Removal of Anthraquinone Dye from aqueous solution using MgO nanocrystallite as an adsorbent

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Abstract

MgO nanocrystallites were used as an adsorbent for the removal of Corolene Blue Anthraquinone dye from an aqueous solution. The adsorption studies were carried out in a batch reactor at various MgO nanocrystallite dosage, initial dye concentrations, solution pH and contact time. Experimental results indicate more than 87% dye removal efficiency of Corolene Blue Anthraquinone dye with dosage of 0.2 g, pH 2, contact time 60 min, for initial dye concentration of 125 mg/L.

Keywords: Adsorption, MgO nanocrystallites, dye removal.

1. Introduction

As per Color Index (C.I), managed by the Society of Dyers and Colorist, recently more than 10,000 types of dyes are synthesised in the world [1] and an annual production of more than 700,000 tonnes have been reported [1,2]. Dyes are an organic compound which consists of two main groups of compounds, chromophores (gives colour of dye) and auxochromes (gives intensity of colour). Based on chromophores, 20-30 different groups of dyes can be categorized of which azo, anthraquinone, phthalocycanine and triarilmethane are recognised as most important groups. Anthraquinone dyes contribute 15% of the total dyes produced in the world [1,3]. Dyes find its applications in various industries including textile, foodstuff, plastic, cosmetics and many more.

One of the major environmental concerns in today's world is the discharge of coloured effluents [1,4]. Dyes are significant pollutants causing environmental problems and health hazards to humans and aquatic creatures as majority of the dyes are toxic and carcinogenic [5,6]. The presence of dyes in aquatic ecosystem not creates an aesthetic issue but decreases photosynthetic activity due to reduction in penetration of sunlight posing a threat on aquatic flora and fauna [1,5,6,7].

Many methods have been reported for the treatment of dye containing effluents which include biological processes, combined chemical and biochemical processes, chemical oxidation, membrane filtration, coagulation, flocculation, separation, reverse osmosis and adsorption [1,7,8]. Each of these methods has specific merits and demerits [1]. Amongst all the methods, adsorption process is one of the most effective and efficient method for removal of dyes, pigments and colorants [6,7,9]. Adsorption is an effective physical process for decolourisation of wastewater which is even economically feasible [10]. Various adsorbents have been used in effective removal of certain colours from aqueous effluents amongst which activated carbon [11] has been the most commonly used adsorbent [1,7,11] but the disadvantage of using it is high production and treatment cost [1,10]. Also various low cost adsorbents like hen feathers [4], agricultural wastes, neem leaves, used black tea, wool, sugar beet pulp, rice husk and many more have been reported. Many researchers all over the world are trying to optimise adsorption and develop novel adsorbents with high adsorptive capacity and low cost which has led to the recent developments and attention to nanotechnology [10].

Researchers worldwide are working on the use of nanoparticles as adsorbent for the removal of dyes. Much attention and effort are put to the synthesis and characterisation of nanostuctured materials due to their unique physical and chemical characteristics [6]. Nano-structured materials compared to micron-sized materials possess a unique characteristic of having large specific surface areas enabling large fraction of atoms available for chemical reaction with very little internal diffusion resistance [1,6]. Nano-sized magnesium oxide MgO serves as a promising material for the application as adsorbents due their high surface area, adsorption capacity and simplicity in their production [1,6]. As the pH of

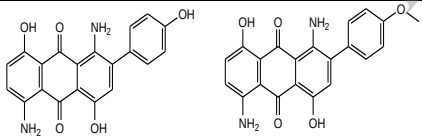
zero point charge (pHzpc) of MgO is 12.4, it is a suitable adsorbent for adsorption of anions because of its electrostatic attraction mechanism [1].

The present study focuses on the use of MgO nanocrystallite for the colour removal of Corolene Blue Anthraquinone Dye. Disperse Blue 73 was selected as a model of anthraquinone dye for dye removal investigations. The effect of different variables including initial pH of the solution, dosage of MgO and reaction/contact time were studied and analysed.

2. Experimental

2.1 Basic properties of the dye under investigation

Table1: Details of Anthraquinone dye

Commercial name of the dye	Coralene Blue BGFS
Chemical name of the dye	Mixture of 1,5-Diamino-4,8-dihydroxy (p-hydroxyphenyl) anthraquinone & 1,5-Diamino-4,8-dihydroxy (p-methoxyphenyl) anthraquinone
Chemical formula	$C_{20}H_{14}N_2O_5$ & $C_{21}H_{16}N_2O_5$
Class	Anthraquinone
C.I number	C.I. Disperse Blue 73
Molecular weight (g/mol)	362 & 376
Molecular structure	

2.2 Chemicals and reagents

The materials used for the experiment were magnesium chloride hexahydrate ($MgCl_2$ $6H_2O$), sodium hydroxide pellets (NaOH), potassium hydroxide pellets (KOH), hydrochloric acid (HCl), (Finar Chemicals Limited, Ahmedabad, Gujarat, India).

2.3 Preparation of MgO

The synthesis of MgO nanocrystallites by sol-gel method with 1N KOH as base is already described in our previous work [12].

2.4 Dye Removal Experiments

Batch adsorption experiments were performed to evaluate adsorption of dye onto synthesized MgO nanocrystalites. Batch tests were performed in 250 ml flask under magnetic stirring. A 100ml of dye solution of known concentration was poured into flask and a known mass of MgO powder was added to solution. The suspension was stirred immediately for predefined time. Samples (aliquots) were collected at preselected time and centrifuged at 3500 rpm for 5 minutes. The residual concentration of dye was noted by UV spectrophotometer. The batch practical were performed at varying dye concentration (75ppm-150ppm), for pH 2-11, MgO dosage (0.1g-0.4g), mixing/contact time (5-120min) and at room temperature. pH was adjusted in each flask with the help of pH meter. The initial pH value of the dye was adjusted to the desired pH using 0.1N HCl or 0.1N NaOH solution. The adsorption percent of each of the dye i.e. the dye removal efficiency was determined using the following expression:

$$\text{Dye removal efficiency (\%)} = \frac{(C_i - C_f)}{C_i} \times 100$$

where C_i and C_f represent the initial and final (after adsorption) dye concentrations respectively.

The effects of pH of the solution, initial dye concentration, MgO dosage, and the mixing/ contact time on the dye removal efficiency by the synthesised MgO nanocrystallite were studied.

3. Results and discussion

3.1 Effect of pH

The effect of pH on the adsorption performance was studied by conducting batch experiments at 125 ppm dye solution of different initial pH values (2-11). The experiment was carried out with 0.2 g of MgO nanocrystallites at room temperature for up to 60 min time, the results of which are shown in table 2 below. Fig. 1 shows that the dye removal efficiency is maximum at pH 2 and minimum at pH 7. From table 2, it can be noted that the initial pH of the dye solution is an important parameter affecting dye removal efficiencies.

Table2: Dye Removal (%) for solution at different Initial pH

pH	2	3	5	7	9	11
Dye Removal (%)	87.22	76.33	63.67	59.24	60.25	72.66

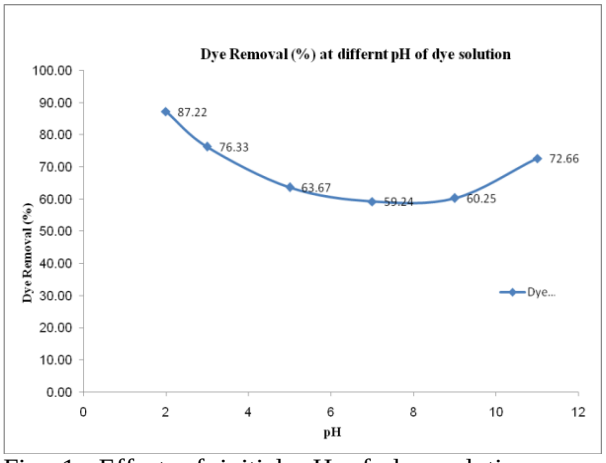


Fig. 1: Effect of initial pH of dye solution on removal of disperse blue 73 anthraquinone dye (MgO dosage = 0.2 g, initial dye concentration = 125 mg/L, contact time = 60 min).

3.2 Effect of contact time

Contact time between adsorbate and adsorbent is the most important parameter affecting the performance of adsorption process. The effect of contact/stirring time on the dye removal efficiency by MgO nanocrystallite was investigated. The batch experiments were conducted for 125 ppm dye solution of initial pH 2 at varying contact time. The results are shown in table 3. From fig. 2, it can be seen that more than 44% of dye removal efficiency is achieved in first 5 minutes. With increase in contact time, the dye removal efficiency also increases. More than 87% of the dye removal efficiency is achieved in 60 mins.

Table 3: Dye Removal (%) for solution at different contact/stirring time

Contact Time (min)	0	5	15	30	45	60
Dye Removal (%)	0.00	44.43	54.18	64.43	80.51	87.22

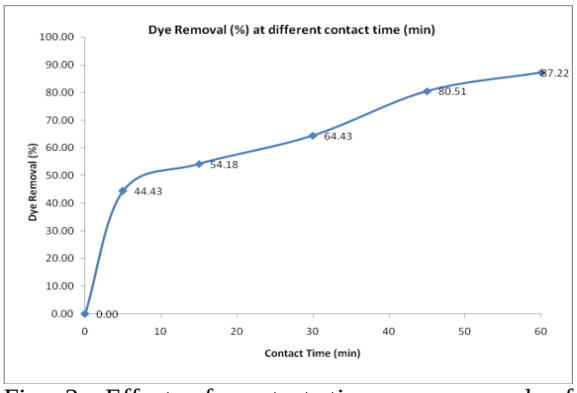


Fig. 2: Effect of contact time on removal of disperse blue 73 anthraquinone dye (MgO dosage = 0.2 g, initial dye concentration = 125mg/L, intial solution pH = 2).

3.3 Effect of adsorbent (MgO) dosage

The effect of MgO dosage on the removal of disperse blue 73 anthraquinone dye is shown in table 4 below. From the results shown in table 4, it is inferred that the dye removal efficiency increases with increase in MgO dosage. The results indicate 0.2 g as optimum dosage. As seen in figure 3, with further increase of MgO dosage above 0.2 g, the removal efficiency remains almost same.

Table4: Dye Removal (%) for solution at different MgO dosage

MgO dosage (g)	0.05	0.1	0.2	0.3	0.4	0.5
Dye Removal (%)	20.55	55.69	87.21	87.50	87.50	87.55

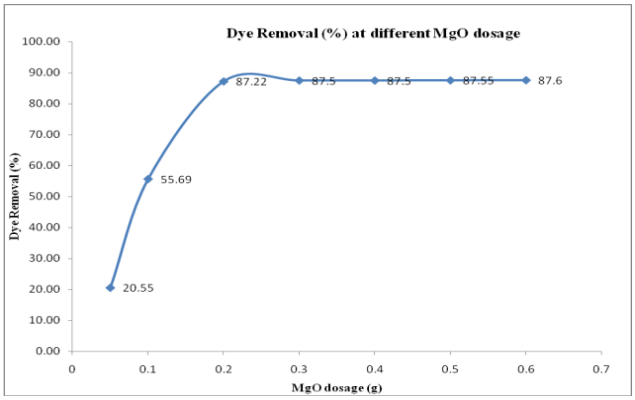


Fig. 3: Effect of (MgO) dosage on removal of disperse blue 73 anthraquinone dye (pH = 2, initial dye concentration= 125 mg/L, contact time = 60 min).

4. Conclusion

The effective removal of dye concentration by adsorption was noted. The synthesised MgO nanocrystallites were effective in removal of dye from the aqueous solution. More than 87% of dye removal with MgO dosage of 0.2 g was observed. The adsorption of dye was dependent on pH of the solution. The maximum removal efficiency was noted at pH2.

5. References

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